

**DISTRIBUTION STATEMENT A**  
Approved for Public Release  
Distribution Unlimited

# **SIGNAL PROCESSING ALGORITHMS**

## **GEORGIA TECH ADA BENCHMARK**

**SPECIAL TECHNICAL REPORT  
REPORT NO. STR-0142-91-014  
AUGUST 5, 1991**

# GUIDANCE, NAVIGATION AND CONTROL DIGITAL EMULATION TECHNOLOGY LABORATORY

Contract No. DASG60-89-C-0142  
Sponsored By  
The United States Army Strategic Defense Command

# COMPUTER ENGINEERING RESEARCH LABORATORY

Georgia Institute of Technology  
Atlanta, Georgia 30332-0540

## Contract Data Requirements List Item A008

Period Covered: Not Applicable

### Type Report: As Required

**Reproduced From  
Best Available Copy**

20010822 029

UL13479

## **DISCLAIMER**

**DISCLAIMER STATEMENT** – The views, opinions, and / or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other official documentation.

## **DISTRIBUTION CONTROL**

- (1) **DISTRIBUTION STATEMENT** – Approved for public release; distribution is unlimited.
- (2) This material may be reproduced by or for the U.S. Government pursuant to the copyright license under the clause at DFARS 252.227-7013, October 1988.

**SIGNAL PROCESSING ALGORITHMS  
GEORGIA TECH ADA BENCHMARK**

AUGUST 5, 1991

---

**RANI INDAHENG**

**COMPUTER ENGINEERING RESEARCH LABORATORY**

Georgia Institute of Technology  
Atlanta, Georgia 30332-0540

---

Eugene L. Sanders  
USASDC  
Contract Monitor

Cecil O. Alford  
Georgia Tech  
Project Director

---

Copyright 1991  
Georgia Tech Research Corporation (GTRC)  
Centennial Research Building  
Atlanta, Georgia 30332

<b>1</b>	<b>Introduction</b>	<b>1</b>
<b>2</b>	<b>Harness</b>	<b>1</b>
2.1	Description	1
2.2	Module Listing	2
<b>3</b>	<b>Non-Uniformity Compensation</b>	<b>5</b>
3.1	Description	5
3.2	Data Fields	5
3.3	Module Listing	5
<b>4</b>	<b>Spatial Filtering</b>	<b>10</b>
4.1	Description	10
4.2	Data Fields	11
4.3	Module Listing	11
<b>5</b>	<b>Temporal Filtering</b>	<b>16</b>
5.1	Description	16
5.2	Data Fields	16
5.3	Module Listing	17
<b>6</b>	<b>Thresholding</b>	<b>21</b>
6.1	Simple Thresholding	21
6.1.1	Data Fields	21
6.1.2	Module Listing	22
6.2	Adaptive Thresholding	25
6.2.1	Data Fields	25
6.2.2	Module Listing	25
<b>7</b>	<b>Clustering and centroiding</b>	<b>29</b>
7.1	Description	29
7.2	Data Fields	29
7.3	Module Listing	30

## 1 INTRODUCTION

This document describes a set of signal-processing algorithms, as implemented by the Computer Engineering Research Laboratory at Georgia Tech. The routines are presented as a representative collection of operations for processing Infrared Focal-Plane Array signals. This Ada version of the benchmark follows an earlier Fortran version (Special Technical Report STR-0142-90-008).

For the purposes of testing and dissemination, each algorithm is presented as a stand-alone Ada program. These programs are based upon a core *harness* routine which supports the input/output of a common data format (Georgia Tech Algorithm Evaluation Data Format – described in the Harness section). The modular implementations offer several benefits:

- simplification of the generation of test vectors for the verification of alternate implementations
- capability for testing various algorithm combinations, without re-compilation
- support for multiple language and/or processor-platform implementations

## 2 HARNESS

### 2.1 Description

The *harness* program shown below is the basis of the input/output methodology used by all of the routines in this document. The code implements a simple Pass-Through module which reads a data stream, picking off the FPA pixel data, and writing the data onto an output data stream.

The Georgia Tech Algorithm Evaluation Data Format is a simple ASCII text representation of a data stream. The data stream has two major components – the *Field Header* and the *Field Data*. The harness of each module processes the data stream by reading each line and checking for Field Headers which are relevant to that module. Any lines which are not relevant, or unrecognized, are immediately placed upon the output data stream. As soon as a relevant Field Header is recognized, the Field Data which follows is processed in a manner which is appropriate to that module and Field Header. This scheme provides for the chaining of modules output-to-input, without either module requiring knowledge of all, or any, of the other module's data formats. In typical use, controls for many modules could be included in a single data stream; each module would only process data intended for it. For example, suppose a test setup was composed of the following pipeline:

Input data stream —> Spatial Filter —> Simple Threshold —> Output Data Stream

The data stream might appear as follows:

Input Data Stream	Description	Used by	Action
Dimensions 128	Field Header Field Data	Spatial Filter and Simple Threshold	input
Simple Thresholding Limits 0 256	Field Header Field Data	Simple Threshold	input
Pixel Data 99 93 ... 81 76 ... . . .	Field Header Field Data Field Data . . .	Spatial Filter and Simple Threshold	input, modified
End	Field Header	Spatial Filter and Simple Threshold	input

Output Data Stream	Description	Generated by	Action
Dimensions 128	Field Header Field Data	Spatial Filter and Simple Threshold	copied to output data stream
Simple Thresholding Limits 0 256	Field Header Field Data	Simple Threshold	copied to output data stream
Simple Thresholding Statistics 0 256 1024	Field Header Field Data	Simple Threshold	generated, then placed on output data stream
Pixel Data 99 93 ... 81 76 ... . . .	Field Header Field Data Field Data . . .	Spatial Filter and Simple Threshold	modified, then placed on output data stream
End	Field Header	Spatial Filter and Simple Threshold	copied to output data stream

## 2.2 Module Listing

```

-- Program      : HARNESS.ada
--               This program acts as a harness for testing
--               various Signal Processing Routines.
-- Original     : Occam Code -> Fortran Code (MicroSoft)
-- Author       : Rani Indaheng
--               A. M. Henshaw
-- Date written: Jan 23, 1990

```

```

-- Note      : Conforms to the Ga. Tech Algorithm Evaluation data
--              format
-----
-- Contact   : Rani Indaheng      (404)894-3802
--              Andrew Henshaw      (404)894-2521
-- Where     : Computer Engineering Research Laboratory
--              Georgia Institute of Technology
--              400 Tenth St. CRB 390
--              Atlanta, GA 30332-0540
-----
-- Update log :
-- When      Who      What
-- 02.06.91  Rani Indaheng  Convert from Fortran to Ada
-- 02.13.91  Rani Indaheng  Tested
-----
with Text_io; use Text_io;
procedure HARNESS is
    package Int_io is new Integer_io(integer); use Int_io;
    type TwoDimType is array (integer range <>, integer range <>) of
        integer;
    MaxSize: constant integer := 64;
    subtype MaxSizeRange is positive range 1..MaxSize;
    subtype MaxStrSize is positive range 1..72;
    subtype StrType is string(MaxStrSize);
    -- Valid section headers
    Dim   : constant string := "Dimensions";
    Pixels: constant string := "Pixel Data";
    Done  : constant string := "End";
    RunFlag: boolean := TRUE;
    N, StrCount: integer;
    InData, OutData: TwoDimType(MaxSizeRange, MaxSizeRange);
    Header: StrType;

    procedure PASSTHRU (N: in integer;
                        InData: in TwoDimType;
                        OutData: out TwoDimType) is
    begin  -- PASSTHRU
        for row in 1..N loop

```

```

        for col in 1..N loop
            OutData(row,col) := InData(row,col);
        end loop; -- for col loop
        end loop; -- for row loop
    end PASSTHRU;

begin -- HARNESS
    put_line("% Processed by Pass Thru Module.");
    while (RunFlag) loop
        Header := (others => ' ');
        get_line(Header, StrCount);
        if (Header(Header'first..StrCount) = Dim) then
            get(N);
            put_line(Dim);
            put(N); new_line;
        elsif (Header(Header'first..StrCount) = Pixels) then
            for row in 1..N loop
                for col in 1..N loop
                    get(InData(row,col));
                end loop; -- for col loop
            end loop; -- for row loop

            PASSTHRU(N, InData, OutData);
            put_line(Pixels);
            for row in 1..N loop
                for col in 1..N loop
                    put(OutData(row,col));
                end loop; -- for col loop
                new_line;
            end loop; -- for row loop
        elsif(Header(Header'first..StrCount) = Done) then
            put_line(Done);
            RunFlag := FALSE;
        else
            put_line(Header);
        end if;
    end loop; -- while loop
end HARNESS;

```

### 3 NON-UNIFORMITY COMPENSATION

#### 3.1 Description

The non-uniformity compensation algorithm provides a pixel-by-pixel correction of the actual pixel response to the desired response. The current algorithm uses up to a five-point, piecewise-linear correction to the pixel intensity. The correction is determined by sending a specified number of calibration frames through the process. Each of the calibration frames will have been generated by exposing the focal-plane array to a known intensity so that a desired pixel intensity is expected at each pixel.

Dead, or inadequately responsive, pixels are assumed to have been marked by another module and, during processing, they are replaced by the intensity of the previous pixel.

After calibration is performed, the algorithm enters the processing phase. For each pixel which is to be processed, it is first determined if it is a dead pixel. For normal pixels, the calibration intensities are searched to determine which section should be used for correction. After the section is determined, a linear interpolation is performed using the input pixel intensity to interpolate between the desired responses.

#### 3.2 Data Fields

Action	Field Header	Field Data	Data Type
input	Dimensions	FPA dimension	Integer
input	Calibration Frames	Count of calibration frames	Integer
input	Calibration Input	Vector of reference inputs	Integer [1..Count]
input	Calibration Pixel Data	Array of pixel response data for one input reference	Integer [1..Dimension] [1..Dimension]
modified	Pixel Data	Pixel data array	Integer [1..Dimension] [1..Dimension]

#### 3.3 Module Listing

```
-- Program      : NUNICOMP.ada
--                      Non-Uniform Compensation Test Module.
-- Original     : Occam Code -> Fortran Code (MicroSoft)
-- Author       : Rani Indaheng
--                      A. M. Henshaw (Harness)
```

```

--           Steve Giesecking
--           Roy W. Melton
-- Date written: Feb 1, 1990
-- Note      : Conforms to the Ga. Tech Algorithm Evaluation
--              data Format.

-----
-- Contact      : Rani Indaheng      (404)894-3802
--                  Andrew Henshaw    (404)894-2521
-- Where        : Computer Engineering Research Laboratory
--                  Georgia Institute of Technology
--                  400 Tenth St. CRB 390
--                  Atlanta, GA 30332-0540

-----
-- Update log :
-- When      Who      What
-- 02.06.91  Rani Indaheng  Convert from Fortran to Ada
-- 02.13.91  Rani Indaheng  Tested

-----
with Text_io; use Text_io;
procedure NUNICOMP is
    package Int_io is new Integer_io(integer); use Int_io;
    type OneDimType is array (integer range <>) of integer;
    type TwoDimType is array (integer range <>, integer range <>) of
        integer;
    type ThreeDimType is
        array (integer range <>, integer range <>, integer range <>)
        of integer;

    MaxSize      : constant integer := 128; -- Max FPA size
    MaxCalFrames: constant integer := 5;    -- Default number of frames

    subtype MaxSizeRange is positive range 1..MaxSize;
    subtype MaxCalFramesRange is positive range 1..MaxCalFrames;
    subtype MaxStrSize is positive range 1..72;
    subtype StrType is string(MaxStrSize);

    -- Valid section headers
    Dim        : constant string := "Dimensions";
    Pixels    : constant string := "Pixel Data";

```

```

Done      : constant string := "End";
Sect      : constant string := "Calibration Frames";
CalInput  : constant string := "Calibration Input";
CalOutput: constant string := "Calibration Output";

RunFlag: boolean := TRUE;
Header: StrType;
N, StrCount, Count, Sections: integer;
InData, OutData: TwoDimType (MaxSizeRange, MaxSizeRange);
Ic: OneDimType (MaxCalFramesRange);
Oc: ThreeDimType (MaxCalFramesRange, MaxSizeRange, MaxSizeRange);

procedure NON_UNIFORMITY_COMPENSATION(N, Sections: in integer;
                                      Ic: in OneDimType;
                                      Oc: in ThreeDimType;
                                      InData: in TwoDimType;
                                      OutData: in out TwoDimType) is
begin
  Limit: constant integer := 65535;
  LastPixel: integer := 0;
  TmpSection: integer;
  -- NON_UNIFORMITY_COMPENSATION
  for row in 1..N loop
    for col in 1..N loop
      if (Oc(1,row,col) = Limit) then
        OutData(row,col) := LastPixel;
      else
        TmpSection := 1;
        while ((TmpSection < (Sections - 1)) and
               (InData(row,col) >=
                Oc(TmpSection + 1, row, col))) loop
          TmpSection := TmpSection + 1;
        end loop;  -- while loop
        if (InData(row,col) < Oc(TmpSection, row, col)) then
          OutData(row,col) := Oc(TmpSection, row, col);
        else
          OutData(row,col) :=
            (InData(row,col) - Oc(TmpSection, row, col))
            * (Ic(TmpSection + 1) - Ic(TmpSection))
            / (Oc((TmpSection + 1), row, col))
        end if;
      end if;
    end loop;
  end loop;
end procedure;

```

```

            - Oc(TmpSection, row, col))
            + Ic(TmpSection);
        end if;
        if (OutData(row, col) > Limit) then
            OutData(row, col) := Limit;
        end if;

        LastPixel := OutData(row, col);
    end if;
end loop; -- for col loop
end loop; -- for row loop
end NON_UNIFORMITY_COMPENSATION;

begin -- NUNICOMP
    Count := 1;
    Sections := MaxCalFrames;
    put_line("% Processed by Non-Uniformity Compensation Module.");

    while(RunFlag) loop
        Header := (others => ' ');
        get_line(Header, StrCount);
        if (Header(Header'first..StrCount) = Dim) then
            get(N);
            skip_line;
            put_line(Dim);
            put(N); new_line;
        elsif (Header(Header'first..StrCount) = Sect) then
            get(Sections);
            skip_line;
            put_line(Sect);
            put(Sections); new_line;
        elsif (Header(Header'first..StrCount) = CalInput) then
            if (Count <= Sections) then
                get(Ic(Count));
                skip_line;
                put_line(CalInput);
                put(Ic(Count)); new_line;
            else

```

```

        put_line(CalInput);
    end if;
    elsif (Header(Header'first..StrCount) = CalOutput) then
        if (Count <= Sections) then
            for row in 1..N loop
                for col in 1..N loop
                    get(Oc(Count, row, col));
                end loop; -- for col loop
            end loop; -- for row loop
            skip_line;

        put_line(CalOutput);
        for row in 1..N loop
            for col in 1..N loop
                put(Oc(Count, row, col));
            end loop; -- for col loop
            new_line;
        end loop; -- for row loop
        Count := Count + 1;
    else
        put_line(CalOutput);
    end if;
    elsif (Header(Header'first..StrCount) = Pixels) then
        if ((Count > 1) and (Sections > 1)) then
            for row in 1..N loop
                for col in 1..N loop
                    get(InData(row, col));
                end loop; -- for col loop
            end loop; -- for row loop
            skip_line;
            if (Count <= Sections) then
                Sections := Count - 1;
            end if;
            NON_UNIFORMITY_COMPENSATION(N, Sections, Ic, Oc, InData,
                                         OutData);
            put_line(Pixels);
            for row in 1..N loop
                for col in 1..N loop
                    put(OutData(row, col));
                end loop;
            end loop;
        end if;
    end if;

```

```
        end loop; -- for col loop
        new_line;
    end loop; -- for row loop
else
    put_line(Pixels);
end if;
elsif (Header(Header'first..StrCount) = Done) then
    put_line(Done);
    RunFlag := FALSE;
else
    put("NOT = ANY.....");
    put_line(Header);
end if;
end loop; -- while loop
end NUNICOMP;
```

## 4 SPATIAL FILTERING

### 4.1 Description

The spatial filtering algorithm performs a convolution of the image with a 3x3 coefficient mask. This implementation supports a four point symmetric mask. Separate masks are used for the edge pixels since not all of the pixels which are needed are defined. This allows more general application of boundary conditions than would be available if the undefined pixels were treated as zeros and the same mask was used.

Since the filter allows negative coefficients in the mask, it is possible to generate negative output intensities. The coding allows the intensity to be output limited to a positive range.

## 4.2 Data Fields

Action	Field Header	Field Data	Data Type
input	Dimensions	FPA dimension	Integer
input	Spatial Filter Control	Filter coefficients (Corner coefficients)	Integer [1..4]
		Filter coefficients (Top coefficients)	Integer [1..4]
		Filter coefficients (Right coefficients)	Integer [1..4]
		Filter coefficients (Center coefficients)	Integer [1..4]
modify	Pixel Data	Pixel data array	Integer [1..Dimension] [1..Dimension]

## 4.3 Module Listing

```
-- Program      : SPFILT.adb
--                  Spatial Filtering Test Module.
-- Original     : Occam Code -> Fortran Code (MicroSoft)
-- Author       : Rani Indaheng
--                  A. M. Henshaw (Harness)
--                  Steve Gieseking
--                  Roy W. Melton
-- Date written: Jan 23, 1990
-- Note         : Conforms to the Ga. Tech Algorithm Evaluation data
--                  Format.

-----
-- Contact      : Rani Indaheng      (404) 894-3802
--                  Andrew Henshaw      (404) 894-2521
-- Where        : Computer Engineering Research Laboratory
--                  Georgia Institute of Technology
--                  400 Tenth St. CRB 390
--                  Atlanta, GA 30332-0540

-----
-- Update log :
-- When      Who      What
-- 02.06.91  Rani Indaheng  Convert from Fortran to Ada
```

```

-- 02.13.91 Rani Indaheng Tested
-----
with Text_io; use Text_io;
procedure SPFILT is
    package Int_io is new Integer_io(integer); use Int_io;
    type TwoDimType is array (integer range <>, integer range <>) of
        integer;

    MaxSize  : constant integer := 64;  -- Max FPA size
    SFCtrlSize: constant integer := 4;   -- Spatial Control Size

    subtype MaxSizeRange is positive range 1..MaxSize;
    subtype SFCtrlSizeRange is positive range 1..SFCtrlSize;
    subtype MaxStrSize is positive range 1..72;
    subtype StrType is string(MaxStrSize);

    -- Valid section headers
    Dim      : constant string := "Dimensions";
    Pixels   : constant string := "Pixel Data";
    Done     : constant string := "End";
    Controls: constant string := "Spatial Filter Controls";

    RunFlag: boolean := TRUE;
    Header: StrType;
    N, StrCount: integer;
    InData, OutData: TwoDimType(MaxSizeRange, MaxSizeRange);
    C: TwoDimType(SFCtrlSizeRange, SFCtrlSizeRange);

    procedure DEFAULT_FILTER_CTRLS(C: out TwoDimType) is
    begin  -- DEFAULT_FILTER_CTRLS
        for row in 1..4 loop
            for col in 1..3 loop
                C(row,col) := 0;
            end loop;  -- col

            C(row,4) := 16384;
        end loop;  -- row
    end DEFAULT_FILTER_CTRLS;

```

```

procedure SPATIAL_FILTER(N: in integer;
                        C, InData: in TwoDimType;
                        OutData: out TwoDimType) is
  LowLimit: constant integer := 0;
  UpLimit : constant integer := 65535;
begin  -- SPATIAL_FILTER
  for row in 1..N loop
    for col in 1..N loop
      if (row = 1) then
        if (col = 1) then
          OutData(row,col) := (InData(row+1,col+1) * C(1,1)) +
                               (InData(row,col+1)   * C(1,2)) +
                               (InData(row+1,col)  * C(1,3)) +
                               (InData(row,col)    * C(1,4));
        elsif (col = N) then
          OutData(row,col) := (InData(row+1,col-1) * C(1,1)) +
                               (InData(row,col-1)   * C(1,2)) +
                               (InData(row+1,col)  * C(1,3)) +
                               (InData(row,col)    * C(1,4));
        else
          OutData(row,col) :=
            ((InData(row+1,col-1) + InData(row+1,col+1)) *
             C(2,1)) +
            ((InData(row,col-1)   + InData(row,col+1))   *
             C(2,2)) +
            (InData(row+1,col)   *
             C(2,3)) +
            (InData(row,col)     *
             C(2,4));
        end if;  -- col
      elsif (row = N) then
        if (col = 1) then
          OutData(row,col) := (InData(row-1,col+1) * C(1,1)) +
                               (InData(row,col+1)   * C(1,2)) +
                               (InData(row-1,col)  * C(1,3)) +
                               (InData(row,col)    * C(1,4));
        elsif (col = N) then
          OutData(row,col) := (InData(row-1,col-1) * C(1,1)) +
                               (InData(row,col-1)   * C(1,2)) +

```

```

                (InData(row-1,col)    * C(1,3)) +
                (InData(row,col)      * C(1,4));

else
    OutData(row,col) :=
        ((InData(row-1,col-1) + InData(row-1,col+1)) *
        C(2,1)) +
        ((InData(row,col-1)    + InData(row,col+1))   *
        C(2,2)) +
        (InData(row-1,col)    * C(2,3)) +
        (InData(row,col)      * C(2,4));
end if;    -- col
elsif (col = 1) then
    OutData(row,col) :=
        ((InData(row-1,col+1) + InData(row+1,col+1)) *
        C(3,1)) +
        (InData(row,col+1)    * C(3,2)) +
        ((InData(row-1,col)   + InData(row+1,col))   *
        C(3,3)) +
        (InData(row,col)      * C(3,4));
elsif (col = N) then
    OutData(row,col) :=
        ((InData(row-1,col-1) + InData(row+1,col-1)) *
        C(3,1)) +
        (InData(row,col-1)    * C(3,2)) +
        ((InData(row-1,col)   + InData(row+1,col))   *
        C(3,3)) +
        (InData(row,col)      * C(3,4));
else
    OutData(row,col) :=
        ((InData(row-1,col-1) + InData(row+1,col-1) +
        InData(row-1,col+1) + InData(row+1,Col+1)) *
        C(4,1)) +
        ((InData(row,col-1)   + InData(row,col+1))   *

```

```

        C(4,2)) +
        ((InData(row-1,col)    + InData(row+1,col))  *
        C(4,3)) +
        (InData(row,col)          *
        C(4,4));
    end if;    -- row
    OutData(row,col) := OutData(row,col) / 16384;
    if (OutData(row,col) < LowLimit) then
        OutData(row,col) := LowLimit;
    elsif (OutData(row,col) > UpLimit) then
        OutData(row,col) := UpLimit;
    end if;
    end loop;    -- col
    end loop;    -- row
end SPATIAL_FILTER;

begin    -- SPFILT
put_line("% Processed by Spatial Filtering Module.");
DEFAULT_FILTER_CTRLS(C);

while(RunFlag) loop
    Header := (others => ' ');
    get_line(Header, StrCount);
    if (Header(Header'first..StrCount) = Dim) then
        get(N);
        put_line(Dim);
        put(N); new_line;
    elsif (Header(Header'first..StrCount) = Pixels) then
        for row in 1..N loop
            for col in 1..N loop
                get(InData(row,col));
            end loop;    -- for col loop
        end loop;    -- for row loop
        SPATIAL_FILTER(N, C, InData, OutData);
        put_line(Pixels);
        for row in 1..N loop
            for col in 1..N loop
                put(OutData(row,col));
            end loop;    -- for col loop
        end loop;    -- for row loop
    end if;
end loop;

```

```

        new_line;
    end loop; -- for row loop
    elsif (Header(Header'first..StrCount) = Controls) then
        for row in SFCtrlSizeRange loop
            for col in SFCtrlSizeRange loop
                get(C(row,col));
            end loop; -- for col loop
        end loop; -- for row loop
        put_line(Controls);
        for row in SFCtrlSizeRange loop
            for col in SFCtrlSizeRange loop
                put(C(row,col));
            end loop; -- for col loop
            new_line;
        end loop; -- for row loop
    elsif (Header(Header'first..StrCount) = Done) then
        put_line(Done);
        RunFlag := FALSE;
    else
        put_line(Header);
    end if;
    end loop; -- while loop
end SPFILT;

```

## 5 TEMPORAL FILTERING

### 5.1 Description

The temporal filtering algorithm provides a pixel-by-pixel infinite impulse response (IIR) filtering of the sequence of images which are sent through the process. This implementation allows up to a fourth-order filter.

### 5.2 Data Fields

Action	Field header	Field Data	Data Type
input	Dimensions	FPA dimension	Integer
input	Temporal Filtering Limits	Lower limits	Integer
		Upper limits	Integer
modify	Pixel Data	Pixel data array	Integer [1..Dimension] [1..Dimension]

### 5.3 Module Listing

```
-- Program      : TMPFILT.ad
--                  Temporal Filter Test Module.
-- Original     : Occam Code -> Fortran Code (MicroSoft)
-- Author       : Rani Indaheng
--                  A. M. Henshaw (Harness)
--                  Steve Giesecking
--                  Roy W. Melton
-- Date written: Jan 23, 1990
-- Note         : Conforms to the Ga. Tech Algorithm Evaluation data
--                  Format.
```

---

```
-- Contact     : Rani Indaheng      (404)894-3802
--                  Andrew Henshaw      (404)894-2521
-- Where        : Computer Engineering Research Laboratory
--                  Georgia Institute of Technology
--                  400 Tenth St. CRB 390
--                  Atlanta, GA 30332-0540
```

---

```
-- Update log :
-- When      Who      What
-- 02.06.91  Rani Indaheng  Convert from Fortran to Ada
```

---

```
with Text_io; use Text_io;
procedure TMPFILT is
  package Int_io is new Integer_io(integer); use Int_io;
  type OneDimType is array (integer range <>) of integer;
  type TwoDimType is array (integer range <>, integer range <>) of
    integer;

  type FourDimType is array (integer range <>, integer range <>,
    integer range <>, integer range <>) of integer;

  MaxSize  : constant integer := 64;    -- Max FPA size
  TFCtrlSize: constant integer := 24;   -- Temporal Filter size

  subtype MaxSizeRange is positive range 1..MaxSize;
  subtype TFCtrlSizeRange is positive range 1..TFCtrlSize;
```

```

subtype MaxStrSize is positive range 1..72;
subtype StrType is string(MaxStrSize);

-- Valid section headers
Dim    : constant string := "Dimensions";
Pixels: constant string := "Pixel Data";
Done   : constant string := "End";
Limits: constant string := "Temporal Filtering Limits";

RunFlag: boolean := TRUE;
Lower  : integer := 0;      -- default value
Upper  : integer := 32767;  -- default value
Header: StrType;
N, StrCount: integer;
InData, OutData: TwoDimType(MaxSizeRange, MaxSizeRange);
C: OneDimType(TFCtrlSizeRange);

procedure TMP_FILTER(N: in integer;
                     C: in OneDimType;
                     InData: in TwoDimType;
                     OutData: out TwoDimType) is

  TF_A0          : constant integer := 1;
  TF_A1          : constant integer := 2;
  TF_A2          : constant integer := 3;
  TF_B0          : constant integer := 4;
  TF_B1          : constant integer := 5;
  TF_B2          : constant integer := 6;
  TF_SCALE_STATE : constant integer := 7;
  TF_SCALE_OUTPUT : constant integer := 8;
  TF_UPPER_LIMIT_STATE : constant integer := 9;
  TF_LOWER_LIMIT_STATE : constant integer := 10;
  TF_UPPER_LIMIT_OUTPUT: constant integer := 11;
  TF_LOWER_LIMIT_OUTPUT: constant integer := 12;
  Xnew, Ynew, Ptr, Value: integer;
  X: FourDimType(MaxSizeRange, MaxSizeRange, 1..2, 1..2);

begin  -- TMP_FILTER
  for i in MaxSizeRange loop

```

```

for j in MaxSizeRange loop
    for k in 1..2 loop
        for l in 1..2 loop
            X(i,j,k,l) := 0;
        end loop; -- l
    end loop; -- k
end loop; -- j
for i in 1..N loop
    for j in 1..N loop
        Value := InData(i,j);
        for k in 1..2 loop
            Ptr := (k - 1) * 12;
            Xnew := ((C(Ptr + TF_A0) * Value) +
                      (C(Ptr + TF_A1) * X(i,j,k,1)) +
                      (C(Ptr + TF_A2) * X(i,j,k,2))) /
                      C(Ptr + TF_SCALE_STATE);
            Ynew := ((C(Ptr + TF_B0) * Value) +
                      (C(Ptr + TF_B1) * X(i,j,k,1)) +
                      (C(Ptr + TF_B2) * X(i,j,k,2))) /
                      C(Ptr + TF_SCALE_OUTPUT);
            X(i,j,k,2) := X(i,j,k,1);

            if (Xnew > C(Ptr+TF_UPPER_LIMIT_STATE)) then
                X(i,j,k,1) := C(Ptr+TF_UPPER_LIMIT_STATE);
            elsif (Xnew < C(Ptr+TF_LOWER_LIMIT_STATE)) then
                X(i,j,k,1) := C(Ptr+TF_LOWER_LIMIT_STATE);
            else
                X(i,j,k,1) := Xnew;
            end if;
            if (Ynew > C(Ptr+TF_UPPER_LIMIT_OUTPUT)) then
                Value := C(Ptr+TF_UPPER_LIMIT_OUTPUT);
            elsif (Ynew < C(Ptr+TF_LOWER_LIMIT_OUTPUT)) then
                Value := C(Ptr+TF_LOWER_LIMIT_OUTPUT);
            else
                Value := Ynew;
            end if;
        end loop; -- k
    end loop; -- j
end loop; -- i

```

```

        OutData(i,j) := Value;
    end loop; -- j
    end loop; -- i
end TMP_FILTER;

procedure CALCULATE_FILTER_CTRLS(Lower, Upper: in integer;
                                  C: out OneDimType) is
    Step: integer := 0;
begin -- CALCULATE_FILTER_CTRLS
    for i in 1..2 loop
        for j in 1..8 loop
            C(j+Step) := 1;
        end loop; -- j
        C(9+Step) := 3;
        C(10+Step) := 1;
        C(11+Step) := Upper;
        C(12+Step) := Lower;
        Step := Step + 12;
    end loop; -- i

end CALCULATE_FILTER_CTRLS;

begin -- TMPFILT
    put_line("% Processed by Temporal Filtering Module.");
    while(RunFlag) loop
        Header := (others => ' ');
        get_line(Header, StrCount);
        if (Header(Header'first..StrCount) = Dim) then
            get(N);
            put_line(Dim);
            put(N); new_line;
        elsif (Header(Header'first..StrCount) = Pixels) then
            for row in 1..N loop
                for col in 1..N loop
                    get(InData(row,col));
                end loop; -- for col loop
            end loop; -- for row loop
        end if;
    end loop;
end TMPFILT;

```

```

    CALCULATE_FILTER_CTRLS(Lower, Upper, C);
    TMP_FILTER(N, C, InData, OutData);
    put_line(Pixels);
    for row in 1..N loop
        for col in 1..N loop
            put(OutData(row,col));
        end loop; -- for col loop
        new_line;
    end loop; -- for row loop
    elsif (Header(Header'first..StrCount) = Limits) then
        get(Lower);
        get(Upper);
        put_line(Limits);
        put(Lower);
        put(' ');
        put(Upper); new_line;
    elsif (Header(Header'first..StrCount) = Done) then
        put_line(Done);
        RunFlag := FALSE;
    else
        put_line(Header);
    end if;
    end loop; -- while loop
end TMPFILT;

```

## 6 THRESHOLDING

The thresholding algorithm is used to partition the image into points which are of interest and those that are not of interest. Pixels are zeroed if they are not of interest. A pixel is passed if the intensity is above a calculated lower threshold value and below a fixed upper threshold value. The lower threshold supports two of the modes which are in the Georgia Tech VLSI design. This includes a simple, fixed threshold and an adaptive threshold based on the average and first central absolute moment of the surrounding eight pixels.

## 6.1 SIMPLE THRESHOLDING

### 6.1.1 Data Fields

Action	Field Header	Field Data	Data Type
input	Dimensions	FPA dimension	Integer
input	Simple Thresholding Limits	Lower limit	Integer
		Upper limit	Integer
output	Simple Thresholding Statistics	Lower limit used	Integer
		Upper limit used	Integer
		Count of pixels exceeding limit	Integer
modify	Pixel Data	Pixel data array	Integer [1..Dimension] [1..Dimension]

### 6.1.2 Module Listing

```
-- Program      : STHRESH.ada
--                  Simple Thresholding Test Module.
-- Original     : Occam Code -> Fortran Code (MicroSoft)
-- Author       : Rani Indaheng
--                  A. M. Henshaw (Harness)
--                  Steve Giesecking
--                  Roy W. Melton
-- Date written: Jan 23, 1990
-- Note         : Conforms to the Ga. Tech Algorithm Evaluation Data
--                  Format.

-----
-- Contact      : Rani Indaheng      (404)894-3802
--                  Andrew Henshaw      (404)894-2521
-- Where        : Computer Engineering Research Laboratory
--                  Georgia Institute of Technology
--                  400 Tenth St. CRB 390
--                  Atlanta, GA 30332-0540

-----
-- UPDATE LOG
-- When      Who      What
-- 02.07.91  Rani Indaheng  Convert from Fortran to Ada
```

```

-- 02.13.91 Rani Indaheng Tested
-----
with Text_io; use Text_io;
procedure STHRESH is
    package Int_io is new Integer_io(integer); use Int_io;
    type TwoDimType is array (integer range <>, integer range <>) of
        integer;

    MaxSize: constant integer := 128;    -- Max FPA size

    subtype MaxSizeRange is positive range 1..MaxSize;
    subtype MaxStrSize is positive range 1..72;
    subtype StrType is string(MaxStrSize);

    -- Valid section headers
    Dim    : constant string := "Dimensions";
    Pixels: constant string := "Pixel Data";
    Done   : constant string := "End";
    Limits: constant string := "Simple Thresholding Limits";

    Lower  : integer := 0;           -- Default value
    Upper   : integer := 32767;      -- Default value
    RunFlag: boolean := TRUE;
    Header: StrType;
    N, StrCount: integer;
    InData, OutData: TwoDimType(MaxSizeRange, MaxSizeRange);

procedure SMP_THRSH(N, Lower, Upper: in integer;
                    InData: in TwoDimType;
                    OutData: out TwoDimType) is
    Count: integer := 0;
    Pixel: integer;

begin    -- SMP_THRSH
    for row in 1..N loop
        for col in 1..N loop
            Pixel := InData(row,col);
            if ((Pixel >= Lower) and (Pixel <= Upper)) then
                Count := Count + 1;
            end if;
        end loop;
    end loop;
    OutData := InData;
end SMP_THRSH;

```

```

        OutData(row,col) := Pixel;
    else
        OutData(row,col) := 0;
    end if;
    end loop; -- col
end loop; -- row
put_line("Simple Thresholding Statistics");
put(Lower); put(' ');
put(Upper); put(' ');
put(Count); new_line;
end SMP_THRSH;

begin -- STHRESH
put_line("% Processed by Simple Thresholding Module.");

while(RunFlag) loop
    Header := (others => ' ');
    get_line(Header, StrCount);
    if (Header(Header'first..StrCount) = Dim) then
        get(N);
        put_line(Dim);
        put(N); new_line;
    elsif (Header(Header'first..StrCount) = Pixels) then
        for row in 1..N loop
            for col in 1..N loop
                get(InData(row,col));
            end loop; -- for col loop
        end loop; -- for row loop
        SMP_THRSH(N, Lower, Upper, InData, OutData);
        put_line(Pixels);
        for row in 1..N loop
            for col in 1..N loop
                put(OutData(row,col)); put(" ");
            end loop; -- for col loop
            new_line;
        end loop; -- for row loop
    elsif (Header(Header'first..StrCount) = Limits) then
        get(Lower);
        get(Upper);

```

```

        put_line(Limits);
        put(Lower);
        put(' ');
        put(Upper); new_line;
        elsif (Header(Header'first..StrCount) = Done) then
            put_line(Done);
            RunFlag := FALSE;
        else
            put_line(Header);
        end if;
    end loop; -- while loop
end STHRESH;

```

## 6.2 ADAPTIVE THRESHOLDING

### 6.2.1 Data Fields

Action	Field Header	Field Data	Data Type
input	Dimensions	FPA dimension	Integer
input	Adaptive Thresholding Parameters	Upper limit	Integer
		k1	Integer
		k2	Integer
		k3	Integer
		Scale	Integer
output	Adaptive Thresholding Statistics	Upper limit used	Integer
		Count of pixels exceeding limit	Integer
modify	Pixel Data	Pixel data array	Integer [1..Dimension] [1..Dimension]

### 6.2.2 Module Listing

```

-- Program      : ADTHRESH.ada
--                  Adaptive Thresholding Test Module.
-- Original     : Occam Code -> Fortran Code (MicroSoft)
-- Author       : Rani Indaheng
--                  A. M. Henshaw (Harness)

```

```

--                      Steve Giesecking
--                      Roy W. Melton
-- Date written: Jan 23, 1990
-- Note      : Conforms to the Ga. Tech Algorithm Evaluation Data
--              Format.

-----
-- Contact      : Rani Indaheng      (404)894-3802
--                  Andrew Henshaw      (404)894-2521
-- Where        : Computer Engineering Research Laboratory
--                  Georgia Institute of Technology
--                  400 Tenth St. CRB 390
--                  Atlanta, GA 30332-0540

-----
-- UPDATE/TEST LOG
-- When      Who      What
-- 02.07.91  R. Indaheng  Convert from Fortran to Ada
-- 02.13.91  R. Indaheng  Checked with Roy's original

-----
with Text_io; use Text_io;
procedure ADTHRESH is
    package Int_io is new Integer_io(integer); use Int_io;

    type TwoDimType is array (integer range <>, integer range <>) of
        integer;

    MaxSize: constant integer := 64;      -- Max FPA size

    subtype MaxSizeRange is positive range 1..MaxSize;
    subtype MaxStrSize is positive range 1..72;
    subtype StrType is string(MaxStrSize);

    -- Valid section headers
    Dim    : constant string := "Dimensions";
    Pixels: constant string := "Pixel Data";
    Done   : constant string := "End";
   Parms  : constant string := "Adaptive Thresholding Parameters";

    K1    : integer := 1;
    K2    : integer := 0;

```

```

K3      : integer := 0;
Scale   : integer := 8;
Upper   : integer := 32767;    -- Default values
RunFlag: boolean := TRUE;
Header      : StrType;
N, StrCount   : integer;
InData, OutData: TwoDimType(MaxSizeRange, MaxSizeRange);

procedure ADP_THRSH(N, Upper, K1, K2, K3, Scale: in integer;
                     InData: in TwoDimType;
                     OutData: out TwoDimType) is
  Count: integer := 0;
  Sum: integer := 0;
  Average, Stat, Lower, k, l: integer;

begin  -- ADP_THRSH
  for i in 1..N loop
    for j in 1..N loop
      if (((i = 1) or (i = N)) OR ((j = 1) or (j = N))) then
        OutData(i,j) := 0;
      else
        Average := InData(i-1,j-1) + InData(i-1,j) +
                   InData(i-1,j+1) + InData(i,j-1) +
                   InData(i,j+1) + InData(i+1,j-1) +
                   InData(i+1,j) + InData(i+1,j+1);
        Stat := 0;
        k := -2;
        l := -2;
        for indx_k in 1..3 loop
          k := k + 1;
          for indx_l in 1..3 loop
            l := l + 1;
            if ((k /= 0) and (l /= 0)) then
              Stat := Stat + abs((InData(i+k,j+l) * 8) -
                                  Average);
            end if;
          end loop;  -- indx_l
        end loop;  -- indx_k
      end if;
    end loop;
  end if;
end procedure;

```

```

        Lower := ((Average * K1) + (Stat * K2) + K3) / Scale;
        Sum := Sum + Stat;
        if ((InData(i,j) >= Lower) and
            (InData(i,j) <= Upper)) then
            OutData(i,j) := InData(i,j);
            Count := Count + 1;
        else
            OutData(i,j) := 0;
        end if;
        end if;
    end loop; -- j
end loop; -- i
put_line("Adaptive Thresholding Statistics");
put(Upper); put(' ');
put(Count); new_line;
end ADP_THRSH;

begin -- ADTHRESH
put_line("% Processed by Adaptive Thresholding Module.");

while(RunFlag) loop
    Header := (others => ' ');
    get_line(Header, StrCount);
    if (Header(Header'first..StrCount) = Dim) then
        get(N);
        put_line(Dim);
        put(N); new_line;
    elsif (Header(Header'first..StrCount) = Pixels) then
        for row in 1..N loop
            for col in 1..N loop
                get(InData(row,col));
            end loop; -- for col loop
        end loop; -- for row loop
        ADP_THRSH(N, Upper, K1, K2, K3, Scale, InData, OutData);
        put_line(Pixels);
        for row in 1..N loop
            for col in 1..N loop
                put(OutData(row,col));
            end loop; -- for col loop

```

```
        new_line;
    end loop;    -- for row loop
    elseif (Header(Header'first..StrCount) =Parms) then
        get(Upper);
        get(K1);
        get(K2);
        get(K3);
        get(Scale);
        put_line(Parms);
        put(Upper); put(' ');
        put(K1);    put(' ');
        put(K2);    put(' ');
        put(K3);    put(' ');
        put(Scale); new_line;
    elseif (Header(Header'first..StrCount) = Done) then
        put_line(Done);
        RunFlag := FALSE;
    else
        put_line(Header);
    end if;
    end loop;    -- while loop
end ADTHRESH;
```

## 7 CLUSTERING AND CENTROIDING

### 7.1 Description

The clustering algorithm forms connected sets of pixels based on the surrounding pixels. Two pixels are elements of the same cluster of pixels if they are one of the eight nearest neighbors of each other. The centroiding algorithm calculates the area centroid and the intensity weighted centroid of the clusters specified by the clustering algorithm.

## 7.2 Data Fields

Action	Field Header	Field Data	Data Type
input	Dimensions	FPA dimension	Integer
input	Pixel Data	Pixel data array	Integer [1..Dimension] [1..Dimension]
output	Clusters	Cluster count	Integer
output	Centroids	Vector of the following repeated Cluster count times	
		Area centroid (X)	Integer
		Area centroid (Y)	Integer
		Intensity centroid (X)	Integer
		Intensity Centroid (Y)	Integer
		Area in pixels	Integer
		Total cluster intensity	Integer

## 7.3 Module Listing

```
-- Program      : CENTROID.ada
--                  Clustering and Centroiding Test Module.
-- Original     : Occam Code -> Fortran Code (MicroSoft)
-- Author       : Rani Indaheng
--                  A. M. Henshaw (Harness)
--                  Steve Giesecking
--                  Roy W. Melton      Feb 12, 1990
-- Date written: Jan 23, 1990
-- Note         : Conforms to the Ga. Tech Algorithm Evaluation Data
--                  Format.

-----
-- Contact      : Rani Indaheng      (404)894-3802
--                  Andrew Henshaw      (404)894-2521
-- Where        : Computer Engineering Research Laboratory
--                  Georgia Institute of Technology
--                  400 Tenth St. CRB 390
--                  Atlanta, GA 30332-0540

-----
-- UPDATE LOG
```

```

-- When      Who          What
-- 02.07.91  Rani Indaheng Convert from Fortran to Ada
-- 02.13.91  Rani Indaheng Tested
-----
with Text_io; use Text_io;
procedure CENTROID is
    package Int_io is new Integer_io(integer); use Int_io;

    type OneDimType is array (integer range <>) of integer;
    type TwoDimType is array (integer range <>, integer range <>) of
        integer;

    MaxSize      : constant integer := 64;      -- Max FPA size
    MaxClusterSize: constant integer := 1024;    -- Cluster size

    subtype MaxSizeRange is positive range 1..MaxSize;
    subtype MaxClusterSizeRange is positive range 1..MaxClusterSize;
    subtype MaxStrSize is positive range 1..72;
    subtype StrType is string(MaxStrSize);

    -- Valid section headers
    Dim      : constant string := "Dimensions";
    Pixels: constant string := "Pixel Data";
    Done    : constant string := "End";

    RunFlag      : boolean := TRUE;
    Header      : StrType;
    N, StrCount : integer;
    ClusterCount: integer;
    Frame      : TwoDimType(MaxSizeRange, MaxSizeRange);
    Clusters    : TwoDimType(MaxClusterSizeRange, 1..6);

    function SHIFT_RIGTH(Arg: integer) return integer is
    begin  -- SHIFT_RIGTH
        return (Arg / 2);
    end SHIFT_RIGTH;

    procedure CENTROID_IMAGE(N: in integer;
                             Frame: in TwoDimType;

```

```

                ClusterCount: in out integer;
                Clusters: in out TwoDimType) is
        Csum      : constant integer := 1;
        CsumX     : constant integer := 2;
        CsumY     : constant integer := 3;
        Isum      : constant integer := 4;
        IsumX     : constant integer := 5;
        IsumY     : constant integer := 6;
        AcoorX    : constant integer := 1;
        AcoorY    : constant integer := 2;
        IcoorX    : constant integer := 3;
        IcoorY    : constant integer := 4;
        Area      : constant integer := 5;
        Intensity: constant integer := 6;
        C0, C1, Cnml, Cn, Cnpl, FinalCluster: integer;
        Reassign   : OneDimType(0..MaxClusterSize-1);
        TmpClusters: OneDimType(1..MaxSize+1);
        Tmp       : OneDimType(1..6);

begin  -- CENTROID_IMAGE
    for i in 1..N+1 loop
        TmpClusters(i) := 0;
    end loop;  -- i
    FinalCluster := 0;
    Reassign(0) := 0;
    for i in 1..N loop
        -- Initialize row
        C1 := 0;
        Cnpl := 0;
        Cn := TmpClusters(1);
        while (Cn /= Reassign(Cn)) loop
            Cn := Reassign(Cn);
        end loop;  -- while
        for j in 1..N loop
            Cnml := TmpClusters(j+1);
            while (Cnml /= Reassign(Cnml)) loop
                Cnml := Reassign(Cnml);
            end loop;  -- while

```

```

        if (Frame(i,j) = 0) then
            C0 := 0;
        elseif (C1 /= 0) then
            -- Add pixel to cluster
            if ((Cnml /= 0) and (Cnml /= C1)) then
                -- Merge C1, Cnml
                Clusters(C1,Csum) := Clusters(C1,Csum) +
                    Clusters(Cnml,Csum) + 1;
                Clusters(C1,CsumX) := Clusters(C1,CsumX) +
                    Clusters(Cnml,CsumX) + j;
                Clusters(C1,CsumY) := Clusters(C1,CsumY) +
                    Clusters(Cnml,CsumY) + i;
                Clusters(C1,Isum) := Clusters(C1,Isum) +
                    Clusters(Cnml,Isum) +
                    Frame(i,j);
                Clusters(C1,IsumX) := Clusters(C1,IsumX) +
                    Clusters(Cnml,IsumX) +
                    (Frame(i,j) * j);
                Clusters(C1,IsumY) := Clusters(C1,IsumY) +
                    Clusters(Cnml,CsumY) +
                    (Frame(i,j) * i);
                Clusters(Cnml,Csum) := 0;
                Reassign(Cnml) := C1;
                Cnml := C1;
                Cn := Reassign(Cn);
                C0 := C1;
            else
                -- Add to C1
                Clusters(C1,Csum) := Clusters(C1,Csum) + 1;
                Clusters(C1,CsumX) := Clusters(C1,CsumX) + j;
                Clusters(C1,CsumY) := Clusters(C1,CsumY) + i;
                Clusters(C1,Isum) := Clusters(C1,Isum) +
                    Frame(i,j);
                Clusters(C1,IsumX) := Clusters(C1,IsumX) +
                    (Frame(i,j) * j);
                Clusters(C1,IsumY) := Clusters(C1,IsumY) +
                    (Frame(i,j) * i);
                C0 := C1;
            end if;

```

```

        elseif (Cn /= 0) then
            -- Add to Cn
            Clusters(Cn, Csum) := Clusters(Cn, Csum) + 1;
            Clusters(Cn, CsumX) := Clusters(Cn, CsumX) + j;
            Clusters(Cn, CsumY) := Clusters(Cn, CsumY) + i;
            Clusters(Cn, Isum) := Clusters(Cn, Isum) + Frame(i,j);
            Clusters(Cn, IsumX) := Clusters(Cn, IsumX) +
                (Frame(i,j) * j);
            Clusters(Cn, IsumY) := Clusters(Cn, IsumY) +
                (Frame(i,j) * i);

            C0 := Cn;
        elseif (Cnml /= 0) then
            if ((Cnpl /= 0) and (Cnpl /= Cnml)) then
                -- Merge Cnml, Cnpl
                Clusters(Cnml,Csum) := Clusters(Cnml,Csum) +
                    Clusters(Cnpl,Csum) + 1;
                Clusters(Cnml,CsumX) := Clusters(Cnml,CsumX) +
                    Clusters(Cnpl,CsumX) + j;
                Clusters(Cnml,CsumY) := Clusters(Cnml,CsumY) +
                    Clusters(Cnpl,CsumY) + i;
                Clusters(Cnml,Isum) := Clusters(Cnml,Isum) +
                    Clusters(Cnpl,Isum) +
                    Frame(i,j);
                Clusters(Cnml,IsumX) := Clusters(Cnml,IsumX) +
                    Clusters(Cnpl,IsumX) +
                    (Frame(i,j) * j);
                Clusters(Cnml,IsumY) := Clusters(Cnml,IsumY) +
                    Clusters(Cnpl,CsumY) +
                    (Frame(i,j) * i);

                Clusters(Cnpl,Csum) := 0;
                Reassign(Cnpl) := Cnml;
                C0 := Cnml;
            else
                -- Add to Cnml
                Clusters(Cnml, Csum) := Clusters(Cnml, Csum) + 1;
                Clusters(Cnml, CsumX) := Clusters(Cnml, CsumX) + j;
                Clusters(Cnml, CsumY) := Clusters(Cnml, CsumY) + i;
                Clusters(Cnml, Isum) := Clusters(Cnml, Isum) +
                    Frame(i,j);

```

```

        Clusters(Cnml, IsumX) := Clusters(Cnml, IsumX) +
                                (Frame(i,j) * j);
        Clusters(Cnml, IsumY) := Clusters(Cnml, IsumY) +
                                (Frame(i,j) * i);
        C0 := Cnml;
    end if;
    elsif (Cnpl /= 0) then
        -- Add to Cnpl
        Clusters(Cnpl, Csum) := Clusters(Cnpl, Csum) + 1;
        Clusters(Cnpl, CsumX) := Clusters(Cnpl, CsumX) + j;
        Clusters(Cnpl, CsumY) := Clusters(Cnpl, CsumY) + i;
        Clusters(Cnpl, Isum) := Clusters(Cnpl, Isum) +
                                Frame(i,j);
        Clusters(Cnpl, IsumX) := Clusters(Cnpl, IsumX) +
                                (Frame(i,j) * j);
        Clusters(Cnpl, IsumY) := Clusters(Cnpl, IsumY) +
                                (Frame(i,j) * i);
        C0 := Cnpl;
    else
        -- New Cluster
        FinalCluster := FinalCluster + 1;
        C0 := FinalCluster;
        Clusters(C0,Csum) := 1;
        Clusters(C0,CsumX) := j;
        Clusters(C0,CsumY) := i;
        Clusters(C0,Isum) := Frame(i,j);
        Clusters(C0,IsumX) := (Frame(i,j) * j);
        Clusters(C0,IsumY) := (Frame(i,j) * i);
        Reassign(C0) := C0;
    end if;
    TmpClusters(j) := C0;
    -- Update for next column
    C1 := C0;
    Cnpl := Cn;
    Cn := Cnml;
end loop; -- j
end loop; -- i

```

```

-- Output Centroids
ClusterCount := 0;
for i in 1..FinalCluster loop
    if (Clusters(i,Csum) /= 0) then
        -- Valid cluster
        Tmp(AcoorX) := (Clusters(i,CsumX) +
                         SHIFT_RIGTH(Clusters(i,Csum))) /
                         Clusters(i, Csum);
        Tmp(AcoorY) := (Clusters(i,CsumY) +
                         SHIFT_RIGTH(Clusters(i,Csum))) /
                         Clusters(i, Csum);
        Tmp(IcoorX) := (Clusters(i,IsumX) +
                         SHIFT_RIGTH(Clusters(i,Isum))) /
                         Clusters(i, Isum);
        Tmp(IcoorY) := (Clusters(i,IsumY) +
                         SHIFT_RIGTH(Clusters(i,Isum))) /
                         Clusters(i, Isum);
        Tmp(Area) := Clusters(i,Csum);
        Tmp(Intensity) := Clusters(i,Isum);
        ClusterCount := ClusterCount + 1;
        for j in 1..6 loop
            Clusters(ClusterCount,j) := Tmp(j);
        end loop; -- j
    end if;
end loop; -- i
end CENTROID_IMAGE;

begin -- CENTROID
put_line("% Processed by Centroid Image Module.");

while(RunFlag) loop
    Header := (others => ' ');
    get_line(Header, StrCount);
    if (Header(Header'first..StrCount) = Dim) then
        get(N);
        put_line(Dim);
        put(N); new_line;
    elsif (Header(Header'first..StrCount) = Pixels) then
        for row in 1..N loop

```

```

        for col in 1..N loop
            get(Frame(row,col));
        end loop; -- for col loop
    end loop; -- for row loop
    CENTROID_IMAGE(N, Frame, ClusterCount, Clusters);
    put_line(Pixels);
    for row in 1..N loop
        for col in 1..N loop
            put(Frame(row,col));
        end loop; -- for col loop
        new_line;
    end loop; -- for row loop

    put_line("Clusters");
    put(ClusterCount); new_line;

    if (ClusterCount > 0) then
        put_line("Centroids");
        for row in 1..ClusterCount loop
            for col in 1..6 loop
                put(Clusters(row,col));
            end loop; -- col
            new_line;
        end loop; -- row
    end if;
    elsif (Header(Header'first..StrCount) = Done) then
        put_line(Done);
        RunFlag := FALSE;
    else
        put_line(Header);
    end if;
end loop; -- while loop
end CENTROID;

```